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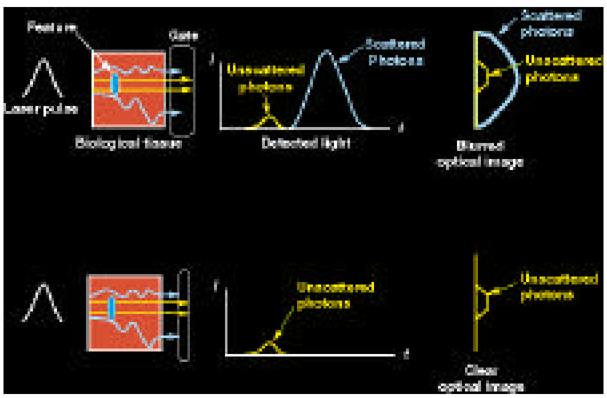
Optical Coherence Tomography for Dental Applications

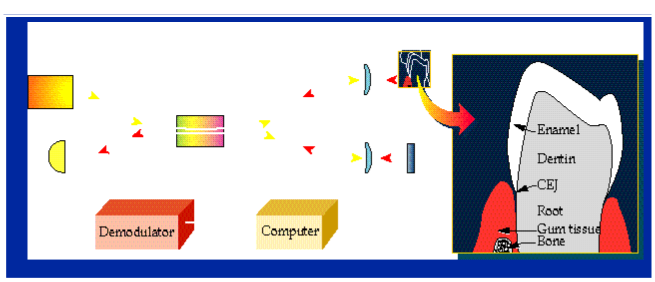
Optical Coherence Tomography (OCT)

Researchers at the Lawrence Livermore National Laboratory are developing a new optical technique for non-invasive imaging of biological tissue. Optical Coherence Tomography (OCT) generates high-resolution (<20 micron) cross-sectional images of tissue, without the need for tissue biopsy. The images are taken using near-infrared light, avoiding the dangers associated with ionizing radiation, as with x-ray images.



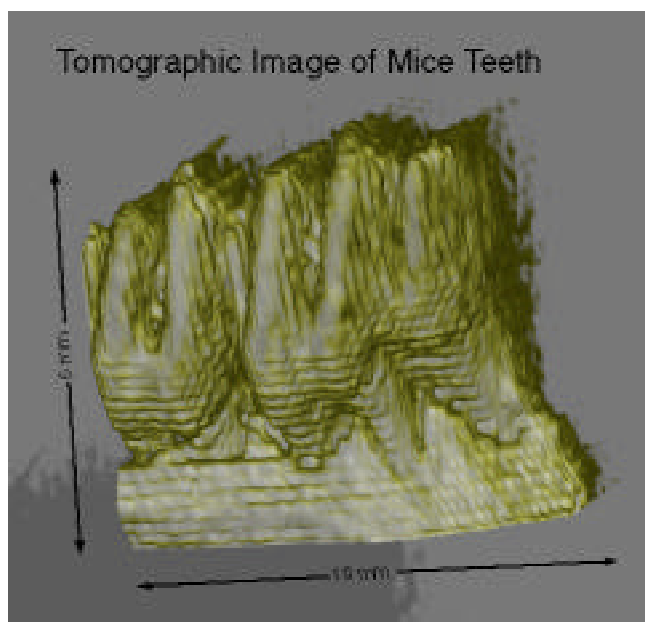
(Top) Scattered photons limits contrast and resolution. (Bottom) In OCT, scattered light can be eliminated using temporal or coherence gating.

Near-infrared light penetrates deeply into tissue, making it useful for imaging of internal structure. The majority of the light, however, is highly scattered as it penetrates into the tissue. These scattered photons dominate in most imaging applications, leading to blurred images. By using a white light Michelson interferometer as a gate, OCT detects only the unscattered "ballistic" photons and is thus able to generate high resolution images. In addition, heterodyning techniques are used to detect very low levels of reflected light from the tissue (10^{-10} reflectivity). OCT is most useful for imaging relatively accessible regions of the body such as skin, internal body cavities, and arteries.



The architecture of the OCT system.

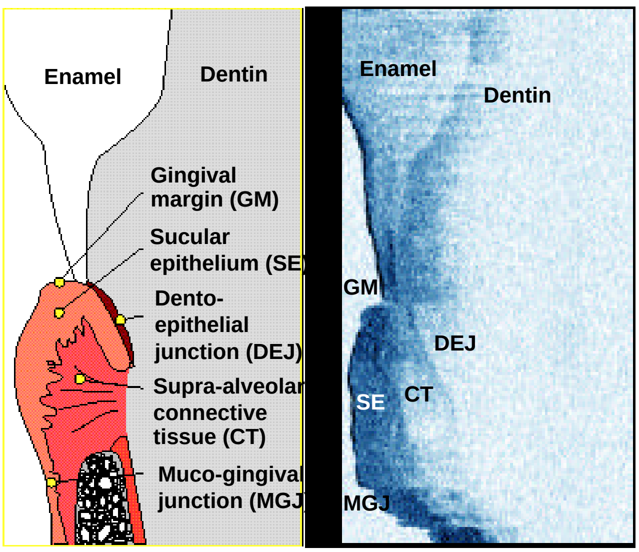
The OCT system is based on a single mode fiber-optic Michelson white light interferometer. High resolution cross-sectional imaging is achieved by focusing light from an optical low coherence source on the biological tissue using a hand-held scanner and measuring the intensities of the backscattered reflections as a function of their axial and transverse positions in the tissue. The light is scanned axially through the tissue by varying the reference arm pathlength. Intensity modulation associated with interference between light from the sample and reference arm reflections (heterodyning) occurs only when the optical pathlengths of the two arms are matched to within the coherence length of the source. The intensity of backscattered light is given by the amplitude of this heterodyned signal and plotted as a function of axial position in the sample, generating one scan. Translating the sample arm transversely generates a series of these scans which are combined to create a two dimensional plot or cross-sectional image of backscattered intensity as a function of transverse and axial position in the tissue.



Cross-sectional images taken with OCT can be combined to give a 3-dimensional representation.

Applications

Periodontal disease diagnosis: Periodontal diseases are plaque-induced disorders that result in loss of connective tissue attachment and resorption of alveolar bone. An important aspect of periodontal disease assessment is determining the location of the soft tissue attachment to the tooth surface. Currently, mechanical or pressure sensitive probes are used to assess periodontal conditions. These probes can be painful for the patient and have several sources of error resulting from variations in insertion force, inflammatory status of tissue, and anatomical tooth contours. OCT is not sensitive to these errors and thus should be a more reproducible and reliable method for determining attachment level. Moreover, directly imaging tooth and soft tissue structures and contour *in vivo* may provide information that would allow diagnosis of periodontal diseases before attachment loss occurs.



In the OCT image (right) the various features of a tooth can be easily distinguished, aiding in diagnosis.

Detection of caries: Dental caries are a common disease that can be easily treated if detected early enough. If undetected and untreated, caries may progress through the outer enamel layer of a tooth into the softer dentin, requiring extraction of the tooth or causing inflammation of the periodontal tissue surrounding the tooth.

The standard methods for detecting caries in teeth are by visual inspection or by the use of dental x-rays. Both methods are unreliable for the detection of small caries. In addition, dental x-rays subject the patient to ionizing radiation, a known mutagen. OCT imaging offers a safe, noninvasive alternative for locating potential and actual sites of caries incursion and therefore improves early disease detection and treatment.

Restoration placement/evaluation: Dental restorations are used to provide a barrier restricting oral fluids and bacteria from entering through the tooth into the systemic system as a result of dental decay or trauma. An inadequate seal can result in a loss of tooth structure, infection, and dissemination of bacteria. The most commonly used methods for evaluating the seal and structural integrity of restorations is visual and tactile examination. OCT has the advantage over these methods of visualizing structural and marginal restoration defects before significant leakage occurs, minimizing tooth loss and decreasing the number of unnecessary replacement restorations.

Continued Research

We are continuing our investigation into further OCT applications.

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